



# HVOF Coatings at Hill AFB



*OGDEN AIR LOGISTICS CENTER*

## ■ AGENDA

- Design Allowables From A-10 Piston Testing
- On-Going Investigations for landing gear applications
  - Duplex Coatings
  - Coating Adherence After Repair Processes
    - Liquid Nitrogen Exposure(Shrink Fits)
    - 375F Bake(Hydrogen Release)
  - Diamond Grinding of 300M Substrate
- Implementation at Hill AFB

Craig Edwards  
ALGLE/Hill AFB

Paul Trester  
ALGLE

Dave Marosok  
Lead Engineer  
Hill AFB

*INNOVATION & EXCELLENCE*

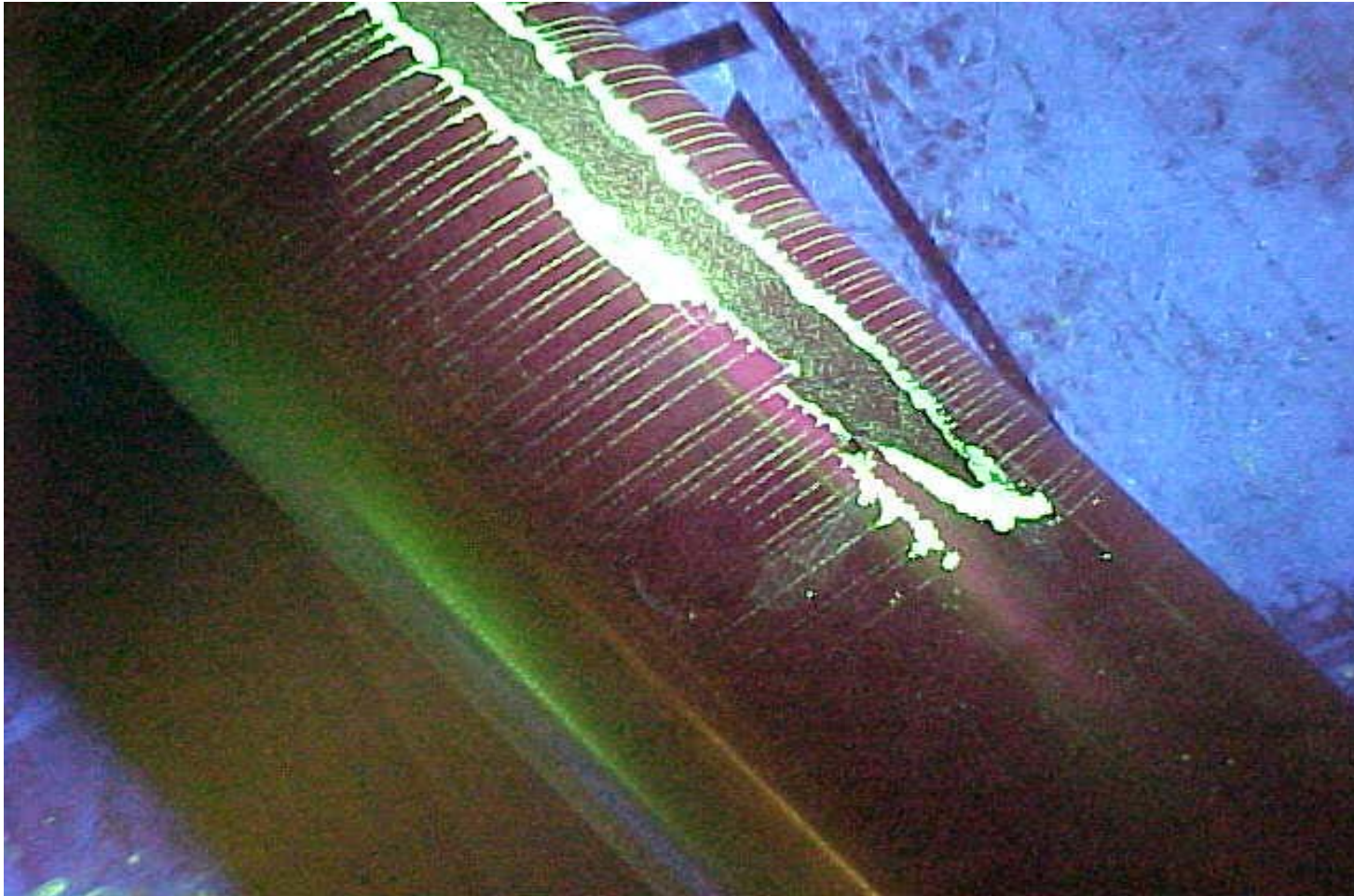
Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>NOV 2003</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-2003 to 00-00-2003</b>	
4. TITLE AND SUBTITLE <b>HVOF Coatings at Hill AFB</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Ogden Air Logistics Center,Hill AFB,UT,84056</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>23rd Replacement of Hard Chrome Plating Program Review Meeting, November 18-19, 2003, Cape Canaveral, FL. Sponsored by SERDP/ESTCP.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>14</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			



# Appearance of Cracks in Coating and Spalled Zone



*OGDEN AIR LOGISTICS CENTER*



*INNOVATION & EXCELLENCE*



# Coating Integrity Testing Summary



OGDEN AIR LOGISTICS CENTER

- **Piston test program(coated with WC-17%Co)**
  - Thick coatings(.010 and .015 inches)
  - Simulated high bending stress conditions
  - Typically 200 cycles above 180 ksi outer fiber bending stress
  - Testing conducted until spallation of coating
    - Spallation occurs near 240 ksi for 0.010 inch thick coating (R= -.33)
- **Air Force landing gear fatigue spectrums have been reviewed(in progress)**
  - Cycles to 180-200 ksi only 30-40 out of 8000 cycles (1 lifetime)
- **Conclusion: HVOF coatings will not spall**
  - Based on bend test results
  - Based on fatigue spectrums reviewed to date



# WC-17%Co Coating Design Allowables



OGDEN AIR LOGISTICS CENTER

<b>R ratio: [Stress Min./ Stress Max.]</b>	<b>Coating Thickness (as-ground)</b>	<b>Allowable Bending Stress: (Mc/l)</b>	<b>Allowable Strain</b>
<b>-0.33</b>	<b>0.010 inches</b>	<b>240 ksi</b>	<b>0.8%</b>
<b>-0.33</b>	<b>0.015 inches</b>	<b>190 ksi</b>	<b>0.67%</b>
<b>-0.41</b>	<b>0.010 inches</b>	<b>240 ksi</b>	<b>0.8%</b>
<b>-0.47</b>	<b>0.010 inches</b>	<b>240 ksi</b>	<b>0.8%</b>
<b>-1.0</b>	<b>0.010 inches</b>	<b>200ksi</b>	<b>0.7%</b>

*INNOVATION & EXCELLENCE*

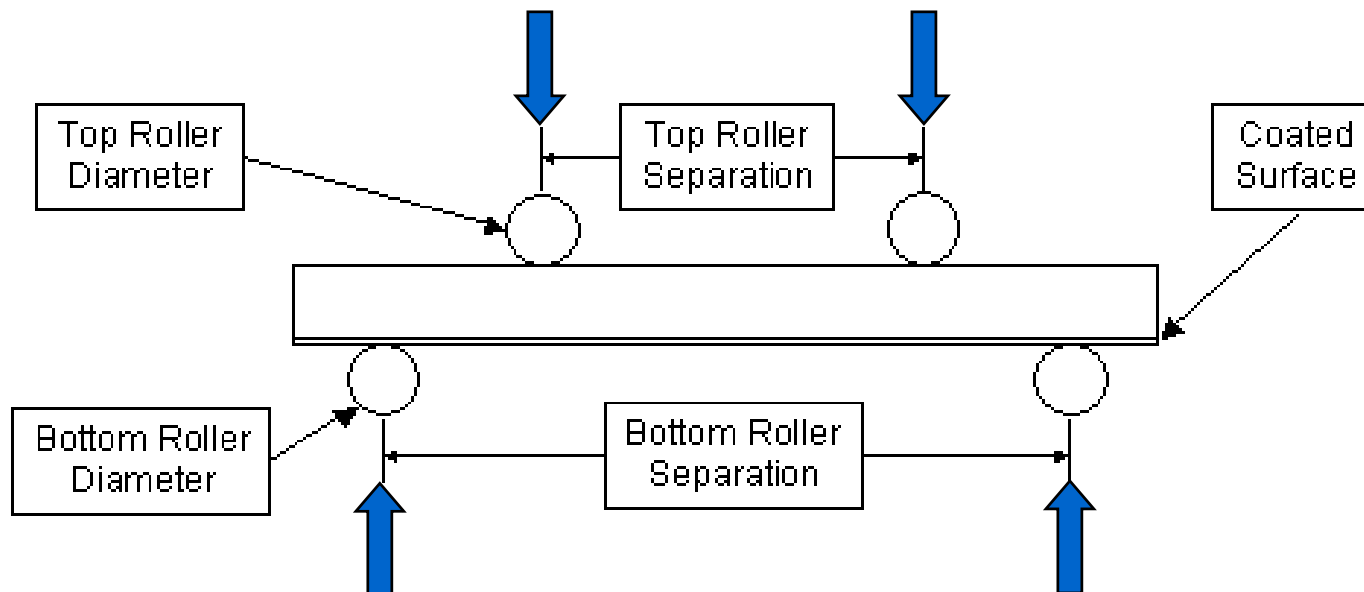


# HVOF Duplex Coatings

OGDEN AIR LOGISTICS CENTER

## ■ Monotonic Testing of Duplex coatings

- Working with Praxair Surface Technologies (Dr. Daming Wang) to investigate duplex coatings for thick build-up repair of landing gear components
- Using 4-pt bend beams(300M) to study strain to fracture and spallation



4-Point Bend Test Schematic





# HVOF Duplex Coatings



*OGDEN AIR LOGISTICS CENTER*

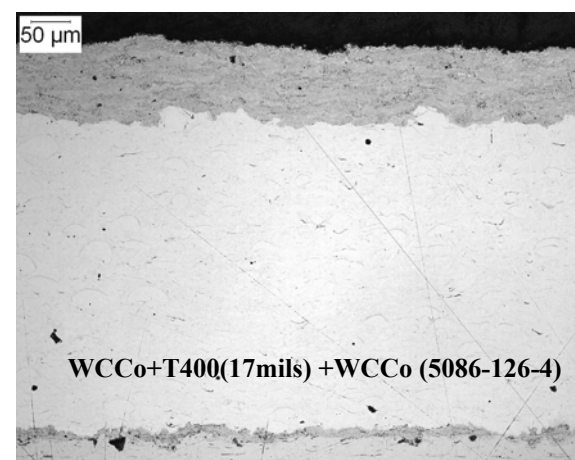
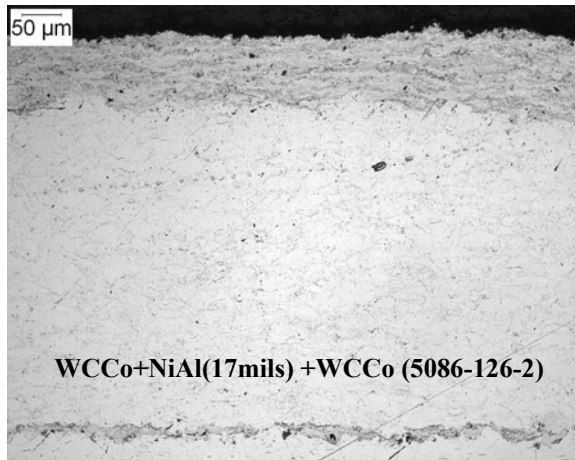
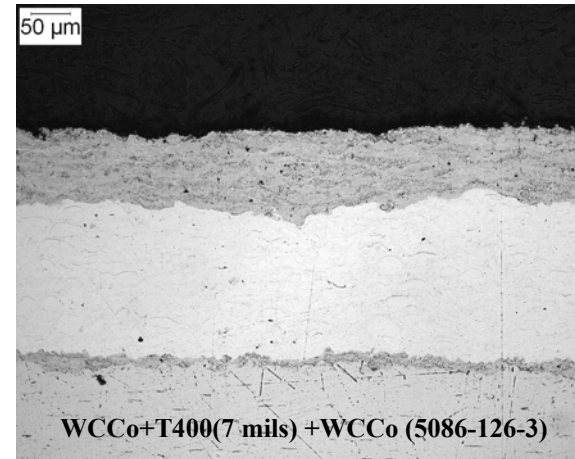
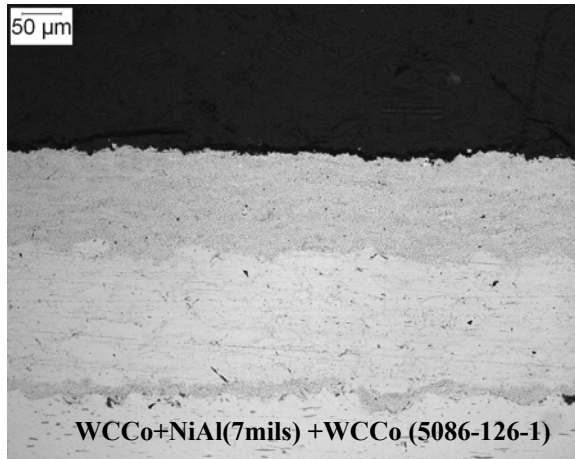
- **Coatings applied via HVOF process on 300M bar**
  - **Replacement for sulfamate nickel build-up and cap with chrome plating**
  - **Bond coat(WC-17%Co)**
  - **Build-up coat(Ni-5%Al and T-400 investigated)**
  - **Topcoat(WC-17%Co)**
- **Benefits**
  - **No surface prep required after each coating application**
  - **One booth, Two powder feeders**
- **Investigating local(patch) repair**



# HVOF Duplex Coating Microstructure



*OGDEN AIR LOGISTICS CENTER*



*INNOVATION & EXCELLENCE*





# HVOF Duplex Coating Bend Test Results



*OGDEN AIR LOGISTICS CENTER*

4 pt Bar Material	Bond Coat	Build-up Coat Sprayed via HVOF process	Topcoat	Spalling near Yield Strength of 300M (230 ksi)???
300M (280-300 ksi)	None	None	WC-17%Co thickness .010	Yes
300M	WC-17%Co thickness .0005-.001	Ni-5%Al thickness .006-.008	WC-17%Co thickness .003-.004 Duplex thickness .010	No
300M	WC-17%Co thickness .0005-.001	Ni-5%Al thickness .016-.018	WC-17%Co thickness .003-.004 Duplex thickness .020	No
300M	WC-17%Co thickness .0005-.001	T-400 thickness .006-.008	WC-17%Co thickness .003-.004 Duplex thickness .010	No
300M	WC-17%Co thickness .0005-.001	T-400 thickness .016-.018	WC-17%Co thickness .003-.004 Duplex thickness .020	Yes

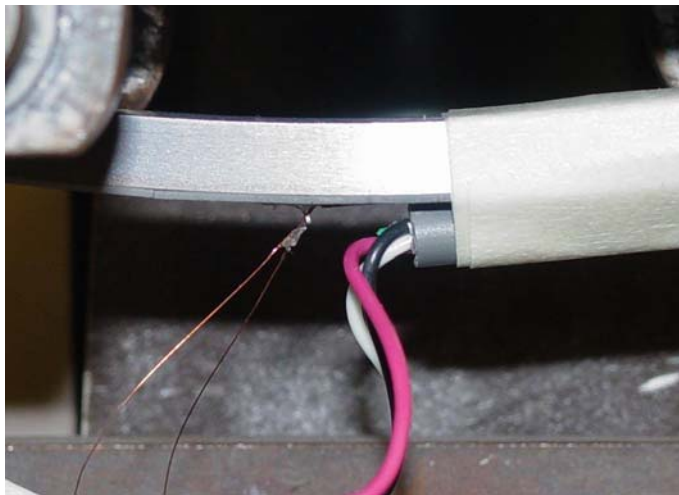
*INNOVATION & EXCELLENCE*



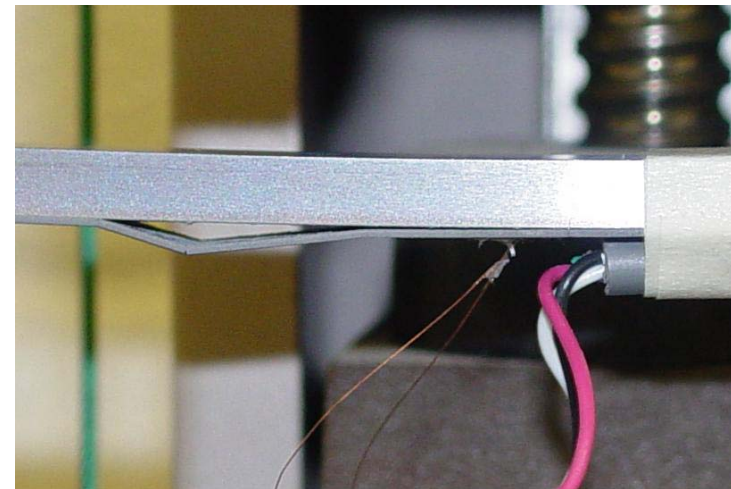
# Spalling of Thick Duplex Coating



*OGDEN AIR LOGISTICS CENTER*



Detection of Spallation Initiation  
During Loading



Spallation When Load is Removed

WC17Co+T400+WC17Co (0.020")  
(1343VM+CO109-7+1343VM)

*INNOVATION & EXCELLENCE*



# 4-Point Bend Test Specimens with Duplex Coating Systems



OGDEN AIR LOGISTICS CENTER



WC17Co+Ni5Al+WC17Co  
(1343VM+NI-356-7+1343VM)



WC17Co+T400+WC17Co  
(1343VM+CO109-7+1343VM)



# Test Findings for Duplex Coatings



OGDEN AIR LOGISTICS CENTER

- **Significant improvement using duplex coating system**
  - Spalling resistance increase
  - Applied bending stress above Yield Strength
  - Substantial permanent deformation observed in bars after test
  - Crack indications observed in top coat
    - Investigation on-going
  - Ni-5%Al appears to be the winner for build-up coat
    - Deposition efficiency higher than WC-17%Co
    - Lower powder cost
    - Weighs less than WC-17%Co
    - Can be sprayed via HVOF process( 1 booth set-up)
    - No surface prep required between coating processes
- **Further investigation being conducted on duplex coatings**
  - Local (patch) repair
  - Fatigue testing



# Recent Findings and On-Going Work



OGDEN AIR LOGISTICS CENTER

- **Coating adherence following standard thermal processes**
  - **Liquid nitrogen testing**
    - Fatigue bar placed in liquid nitrogen
      - Bar tested at 190 ksi, R= -.33
      - No detrimental effects
  - **Hydrogen bake out cycle(375F)**
    - Fatigue bar exposed to two 24 hr bake cycles at 375F
      - Bar tested at 190 ksi, R= -.33
      - No detrimental effects
- **Diamond grinding of 300M steel**
  - **Study conducted with Heroux Devtek**
    - After 0.005 inches of material removal
      - Barkhausen inspection; no defects
      - Diamond wheel dressing with Alumina sticks
    - Total material removed 0.030 inches
      - Nital etch; no defects
    - Investigating diamond grinding of chrome plating





# Implementation at Hill AFB



*OGDEN AIR LOGISTICS CENTER*

- **Masking/fixtures challenge**
  - **Hard masking, only option???**
- **Grinding concerns**
  - **Changing wheels from Al-Oxide to Diamond**
    - Downtime to swap out wheels
- **No specs for spraying and grinding(AMS)**
  - **Hill has developed in-house specifications**
    - Allow tech order changes immediately



# Implementation at Hill AFB



*OGDEN AIR LOGISTICS CENTER*

- **Landing gear components approved for HVOF coating at Hill AFB**
  - **A-10 MLG Piston Barrel**
  - **A-10 NLG Piston Barrel**
  - **B-1 MLG Axle Journals**
  - **C-130 MLG Piston Barrel**
  - **KC-135 NLG Piston Barrel**
  - **KC-135 MLG Piston Barrel**
  - **C-5 MLG Roll Pin Journals**
  - **C-5 MLG Ball Screw Journal**
  - **C-5 MLG Outer Pitch Cylinder**
  - **F-15 Drive Keys**
  - **KC-135 MLG Axle Journals**